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1959

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"The Evaluation of Uncertainties in Inventory Control", Robert B. Fetter, Yale University

Discussion: W. B. Hirschmann, Standard Oil Company (Indiana)

* This is a listing of the papers scheduled for publication. For availability, see preceding page.

THE ENGINEERING ECONOMIST

VOLUME 5 FALL
NUMBER 2 1959

CONTENTS

ARTICLES

Engineering Economy - Teaching and Practice
Billy E. Goetz 1

Project Justification in a Multiproduct Chemical Plant
Andrew Tsu-chao Chang 13

An Extension of Available Interest Tables (Part I)
R. O. Swalm 45

REVIEWS

C. F. Carter & B. R. Williams: Industry and Technical Progress
John H. Norton 29

J. R. Mathews: "How to Administer Capital Spending", Harvard Business Review
Earl E. R. Jones 33

C. T. Grimm & J. G. Gross: Ultimate Cost of Building Walls
John E. Ullmann 40

NOTES

Back Issues & Microfilm Editions 28
Errata 43
Special Subscription Rates 44

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ENGINEERING ECONOMY--TEACHING AND PRACTICE

By

Billy E. Goetz
Massachusetts Institute of Technology

In the ensuing discussion, I propose to follow this sequence of topics:

(1) The desirable content of a course in engineering economy.
(2) A general model of the investment (and replacement) problem.
(3) Considerations in the determination of the critical rate of interest.
(4) Stability and gradients as factors in estimating receipts and disbursements.
(5) The paramount importance of the use of field work.

DESIRABLE CONTENT

If "Engineering Economy" is to include all that its label implies, the course should be drastically enlarged. All "Operations Research" problems involving profit maximizing or cost minimizing are engineering problems with economic objectives and are properly described by the label "Engineering Economy". Thus, while getting an airplane from here to there quickest may be an engineering problem effectively unraveled by "dynamic programming", getting from here to there at least cost or with maximum profit is an engineering economy problem, perhaps also resolvable by dynamic programming. Similarly, submarine hunting may be a technical problem for an operations researcher, but if we want to find submarines at minimum cost, we are back in engineering economy.

Our course at M.I.T. is called "Production Management", which is a misnomer since we omit all of the human problems of the manager (treated in other courses). It does include a wide

variety of problems of production management properly described by the label "Engineering Economy" and often treated under the less descriptive title "Operations Research". For the past three years the course has been closely and completely described by Bowman and Fetter.[1] Briefly, it includes linear and dynamic programming, statistical control, industrial experimentation, inventory and reject planning models, waiting lines, Monte Carlo methods, and investment analysis.

Engineering economists appear to be interested in all of these topics, but seem not to have incorporated them in their courses as yet.

TRADITIONAL CONTENT

Traditionally, the course in engineering economics has been confined to investment analysis: when to replace capital equipment, and which of several alternative investments to make. This paper, while advocating extension to the broader coverage suggested above, will be concerned largely with the teaching of the traditional content of investment analysis.

THE MODEL

A general model, which covers all conceivable problems of investment analysis both with respect to replacement and to selection, is:

$$C = \sum_{t=0}^{T} \frac{(R_t - D_t)}{(1+i)^t} \rightarrow \int_0^T (R_t - D_t) e^{-it} dt$$

where:

C = initial investment $(=D_o)$

R_t = cash receipts during period t or dt (includes R_t = resale)

[1] Edward H. Bowman and Robert B. Fetter: Analysis for Production Management. Richard D. Irwin, Inc., Homewood, Ill., 1957.

D_t = cash disbursements during period t or dt
i = rate of return
T = life of investment

This formula is conceptually usable in either of two ways:

(1) Estimate cash receipts R and cash disbursements D for each period. Estimate initial investment C and life of investment T. Calculate rate of return i. Also estimate a critical rate of return (discussed below). If the calculated rate of return of a specific contemplated investment is greater than the critical rate (the "cutoff level"), the investment should be made. If the calculated rate is below the critical rate, the investment should not be made.

(2) Estimate R and D for each period as above, including C as D_o. (Note that scrap, salvage, or resale value is, of course, included in R_t.) Estimate the critical value of i (see below) for the particular investment contemplated. Differentiate the expression with respect to t, set equal to zero, and solve for T. The differentiation may be done graphically or by tabulation instead of by calculus.

$$\frac{\partial \sum_{t=0}^{T} \frac{(R_t - D_t)}{(1+i)^t}}{\partial t} = 0$$

Using this value of T and the critical value of i, calculate the value of

$$\sum_{t=0}^{T} \frac{(R_t - D_t)}{(1+i)^t} = ?$$

If greater than zero, the investment should be made. If less than zero, the investment should not be made.

If a changing price level is anticipated, problems arise which have not as yet been adequately treated.[2]

[2]B. E. Goetz: "Economics and Engineering Economy", Journal of Engineering Education, Vol. 42, No. 9, May 1952, pp. 436-7.

Aside from the problem of inflation, these models seem general, adequate, correct, foolproof, and practically useless (except to conceptualize and introduce the problem). The real difficulty lies in estimating the R's, D's, T and critical i. By and large, this aspect of engineering economy seems to have been neglected in course work in favor of relatively sterile formula-juggling and routine solution of compound-interest problems.

CRITICAL RATE OF RETURN

While central to the theory of investment, the rate of return to be used in capital-investment formulas (and in economic-lot-size calculations) has usually been carelessly and recklessly assumed. "The company can borrow at 5% -- ." Or, "The company is getting 2% on liquid investments of surplus cash -- ." Or, "The company is generating an implicit, internal rate of return of net profit divided by net worth = 10% -- ." All these and more have appeared in the literature, and in problems at ends of chapters. And all seem naive, erroneous, and misleading, or, as the attorneys say, immaterial and irrelevant. No wonder the sophisticated models of engineering economy have had so little acceptance by practical businessmen. The models regularly give untenable answers because nonsense data are fed into them!

In the first place, averages are irrelevant. We need the marginal rate of return. What additional return can be obtained on additional investment? What incremental return will be lost if investment is reduced a trifle? This incremental concept requires that the highest rate paid or contemplated be used in the investment models. If a company may lose purchase discounts if it ties its funds up in capital assets, the rate to use in the formulas, assuming 2/10/n/30, would be not less than 36%.

Secondly, opportunity costs are the relevant costs, not historical costs. The question is not "How much has the company paid for capital?" but "What return could the company get for some alternative use of its funds?" And this is a subtle and tricky business. Not only must the anticipated return on a

particular contemplated investment be compared with anticipated returns of other contemplated investments, but any reasonable manager must bear in mind new possibilities which may appear tomorrow or next month. If he commits all of his resources -- funds and credit -- now, he may be unable to take advantage of more luscious opportunities offered in the future. Even in the securities markets, investors will often keep sizable proportions of their capital uncommitted, waiting for better bargains later. Businessmen, too, place high value on maintaining a sufficiently liquid position to take advantage of tomorrow's opportunities. This is why payout criteria of two to five years are so common. While a five-year payout is not precisely equivalent to a 20% rate of return, nor a two-year payout to a 50% rate of return, they are of the same orders of magnitude. When an engineering economist plugs in a 5% interest rate (cost of borrowing from a bank), he is likely to get answers which outrage the businessman's intuition. So the businessman clings to his short-payout criteria which give him tenable answers. If engineering economists will recognize the need for liquidity, the alternative of tomorrow's most glittering investment opportunities, and plug in interest rates of 20% to 50%, they may gain more acceptance for their more logical and more sophisticated approach.

Thirdly, following the precedents of the securities markets, different interest rates should be applied for different risks. In the securities markets, competing buyers and sellers have hammered out a logic of rates of return which engineering economists should respect and emulate, just as businessmen already do. A businessman demands a fast payout (50% or better) on short-life assets, or on assets exposed to greater risks of obsolescence. Thus investment in a specialized machine producing a specialized, high-style product, may be judged by a payout of a year or even of a single season. A contemplated investment in standard, multipurpose equipment -- a fork-lift truck, or a universal milling machine -- may be judged by a payout criterion of three or four years; a general, unspecialized manufacturing building in a good industrial location may, due to its longer life, low

obsolescence, ready market, and speculative possibilities on resale, may be judged in terms of a five- to ten-year payout. The engineering economist in search of a single "cutoff" rate by which to separate a multitude of contemplated investments, ranked according to rates of return, into accepted (those above the cutoff rate) and rejected (those below) is doomed to disappointment. There is no one critical rate. Many are needed in solving capital-investment problems just as many are needed in the security markets.

Not only do Podunk incinerator-revenue bonds require a higher yield than United States general-tax-secured bonds, but different rates attach to different maturities. Thus a serial-bond issue, where every bond is secured by the same pledge by the same government, will sell at different yields depending upon maturity date. This is reasonable, since early maturities give quick turnovers and numerous opportunities for the investor to adjust his commitments to new conditions and additional information. Distant maturities expose him to more technological and social change without comparable opportunity to adjust his commitments. To be sure, he can sell, but the very changes which lead him to contemplate selling are likely to be promptly discounted in the market, resulting in losses to the investor. So, too, the engineering economist should attach different interest rates for different investment lives -- higher rates for longer lives -- even though other aspects of alternative investments seem quite similar.

Of course all of these interest rates are related in a loose hierarchy of risks and corresponding rates. In comparing alternate investment opportunities, a businessman might first decide upon a basic marginal interest rate, and modify this rate for risk and maturity for each alternative compared.

ESTIMATING RECEIPTS AND DISBURSEMENTS

The relevant receipts and disbursements are those predicted for all future periods. But prediction itself depends upon stability. If there is <u>no</u> stability, there can be <u>no</u> prediction; but stability is not an all-or-none proposition. It is a matter

of degree, of more or less. Consequently, prediction becomes a matter of confidence intervals, and with the statistician we say, "We believe there is a 95% chance of this cost proving to be \$100 $\pm$ \$10."

Before we predict, we should investigate the stability of the system. Also, we should frequently check the system to see that it remains stable and that we are continuing to deal with the same system. Thus, the theory of probability, of sampling, and of statistical control are necessary to adequate application of engineering economy to practical situations.

Many receipts and disbursements occur in series, with or without trends or gradients. If, with George Terborgh[3], we recognize a tendency of receipts to diminish with age, and of disbursements to increase, and if we assume both to be linear functions, we get the special formula discussed in Chapter 12 of Bowman and Fetter[4]:

$$V = \int_0^T \left[(R-rt)-(D+kt)\right] e^{-it} dt + Se^{-ct}e^{-iT} - B$$

where: V = present value of contemplated investment
R = repetitive series of receipts
r = linear gradient by which R decreases with time
D = repetitive series of disbursements
k = linear gradient by which D increases with time
i = critical interest rate
S = scrap, salvage, or resale value
c = exponential decrease of S with time
T = life of investment
B = installed initial investment

I have taken the liberty of combining several notions presented in the Bowman-Fetter book, and of changing a few of the

[3]Dynamic Equipment Policy. McGraw-Hill Book Company, New York, 1949.
[4]Op. cit.

symbols. Of course, R-rt and D+kt and Se^{-ct} can be replaced by whatever other functions seem appropriate. Since the data are likely to be crude approximations, linear functions are probably as good as any. Note, however, that either R must decrease or D increase or both, as the asset grows older, or the time for replacement will never arrive.

CLASSROOM, READING, AND HOMEWORK

Students can learn something about the theory of models and data collection by reading and by classroom discussion. They can be introduced to such concepts as incremental and opportunity costs. The inadequacies of historical average costs can be effectively caricatured since many ludicrous examples are available.[5] By and large, however, little can be done in teaching data collection via library, classroom, or homework problems. Either data are given the student whether he seeks it or not, or the data are not there and are beyond his most ingenious efforts.

Perhaps the most effective uses of classroom and library are as a source of questions to be investigated in the field and criticism of field work when it is reported back to class.

FIELD WORK

The way to learn data collecting is by collecting data in the field. One summer I taught a terminal course in a Master of Business Administration program. My students had had courses taught by the case method. In my class they were divided into teams. Each team was required to make a "general survey" of a small business using W. H. Newman's "Business Policies and Management"[6] as a guide to subjects to be included. One team studied a cooperative retail food store. Following the Newman-

[5]For some, see my Management Planning and Control, McGraw-Hill Book Company, New York, 1949. See below for others.

[6]Third Edition. South-Western Publishing Company, Cincinnati, Ohio, 1953.

McKinsey outline, they asked the store manager what product lines the store carried. Having always obtained all data from printed texts and cases, these three near-MBAs did not think of looking around the store to see what product lines were offered! Was there a meat counter? Was fresh produce in evidence? Fresh bakery goods? To their credit, they learned their lesson, and in investigating the number of brands offered, they counted the number of cans of each brand of peaches each day and soon felt they could recommend dropping brand X, since the store had not sold a single can of brand X in more than a week.

I propose to illustrate the advantages of field work over case material and classroom discussion by analyzing setup costs in a particular bottling plant. The problem was determining the economic lot size: how much raspberry vodka should be bottled in a batch? The management, at least the chief accountant, had met the lot-size formula:[7]

$$L = \sqrt{\frac{2QB}{UC}}$$

where:
L = economic batch size
Q = period requirements
B = incremental costs per batch
U = incremental cost per unit produced
C = carrying cost per dollar of inventory per period

[7] For a derivation of this formula and a discussion of the content and measurement of each term, see my Management Planning and Control, pp. 206-212. I omitted stockout cost and figured paperwork cost as an average instead of properly as an incremental cost. Otherwise my treatment seems reasonably accurate and adequate. For modifications of the formula to fit various situations, see:

C. W. Churchman, Russell L. Ackoff, and E. Leonard Arnoff, in collaboration with Leslie C. Edie and others: Introduction to Operations Research. John Wiley & Sons, New York, 1957.

J. F. Magee: Production Planning and Inventory Research. McGraw-Hill Book Company, New York, 1958.

Philip M. Morse: Queues, Inventories and Maintenance. John Wiley & Sons, New York, 1958.

T. M. Whitin: Theory of Inventory Management. Princeton University Press, 1953.

He had gathered data as to numerical values of each symbol for raspberry vodka. He had not included paperwork costs nor costs of stockouts in his analysis of B, although both belong there. Here, I shall discuss only the setup component of incremental batch costs in this particular blending and bottling plant.

The important components of setup costs were reported to be:

(1)	Setup labor, three men for one hour at $3 per hour	$ 9
(2)	Learning time, 24 girls on an assembly line, estimated at	80
(3)	Loss in washing out pipes and bottling machine	12
(4)	Loss in alcohol absorption in filters	70

We found that the company employed only three setup men who worked as a team and were paid a straight weekly wage. Moreover, they could handle about 10 to 20% more setups per week without running into any overtime or requiring a fourth man. Similarly, the number of setups could be reduced 20% without reaching a level requiring only two men. Furthermore, no opportunities existed for salvage by putting setup men on other work. They were either setting up or idle. Our conclusion was that setup labor was a fixed cost in this instance and therefore irrelevant. Incremental setup labor cost was zero. Had there been <u>any</u> variable overtime (at 50% premium), much or <u>all</u> setup time would be properly valued at $13.50 per hour for the team. This would be the incremental cost, since setups done in regular hours and eliminated by running larger batches would save overtime labor by rescheduling setup operations.

Learning time also disappeared! Product changes on the bottling line were always made during coffee breaks or at lunch time. Since the company cafeteria could not handle all employees simultaneously, one bottling line at a time closed down for such breaks, and the union contract specified that these breaks could be shifted forwards or backwards from day to day to suit the convenience of the company. Since the work was monotonously repetitive, it was a regular practice for the girls to change stations along the line when they returned from each break. The differences between products were much like the differences between stations.

Consequently there was no lost production due to learning time. The analysis was clinched when it was shown that the assembly belts always ran at standard speed, and production per hour was in fact constant.

When a batch of a new product came through the pipelines and bottling machines, the first dozen or so bottles of the new product were contaminated by residue of the old, and these bottles were valued at $12. We watched the contaminated bottles. After a bit they were dumped into a bucket. Later the bucket was carried upstairs and dumped back into the 300 gallon blending tank! Mixed with 300 gallons of the new product, the contamination by the old was completely insignificant. The real cost involved was the minute or so lost running the contents of a dozen bottles through a second time. Since the first time was done as part of the setup, even this trivial cost disappeared.

Some $10 worth of filter paper is used at a time. After many gallons have been filtered, it gets clogged and must be replaced. However, when the product being run is changed, the contamination of the new product would be too great to be mixed back in as with pipeline and bottling machine contamination. Since alcohol in the filter is tax paid at $10.90 per gallon, and not pre-tax at about $ .50 per gallon, this loss in discarded filter paper seems important. However, a pint bottle can never be filled with precisely a pint, nor can 100 proof ever be precisely 100 proof. Some variation is inevitable, and is recognized by the government in the form of legal allowances or tolerances. A "pint" of "100 proof" must be within these tolerances, and the tolerances are much looser than the precision with which the process can be controlled. The process average can be adjusted to a shade less than a pint and a shade less than 100 proof, and yet even a 3+sigma control limit will lie inside the legal tolerance. This tactic absorbs the dollar losses in alcohol thrown away with discarded filter paper.

We thought we saw a hole. "Why wouldn't your profit be larger if you pursued the same tactic even when no loss was incurred by changing filter papers?" Well, every gallon of alcohol

purchased is reported to the government alcohol-tax unit, and every gallon sold likewise. The control exercised by government inspectors is exceedingly close, and the government doesn't approve of selling more alcohol than is purchased! Hence there is a sharply defined limit on how far profits can be swollen by underfilling and underproofing.

Now were all this detailed in a case, the student could hardly fail to find it, and would learn little by doing the routine arithmetic remaining. The case writer would have done the essential work and benefited by any learning accruing in the process. Only by getting students into plants to make such discoveries for themselves can we produce much student learning. As they bring problems and results back from field to classroom, questioning by fellow students and teacher can probe for the adequacy of analysis and thereby assist in the learning.

SUMMARY

Let us recapitulate the argument:

(1) "Engineering Economy" should be broadly conceived as including all engineering problems with economic objectives.

(2) The traditional content of investment and replacement analysis is easily summarized by a single, simple formula. After a few minutes developing and discussing this formula, the course can get down to its proper business: the methods of estimating the data required to reach conclusions.

(3) The traditional treatment of investment analysis tends to use the wrong interest rate, and usually one much too low adequately to reflect exposure to risk and opportunity costs (particularly the cost of tomorrow's opportunity).

(4) The most effective, if not the only, way to expose students to the problems of data gathering is to send them into the field to develop data, followed by rigorous criticism of the methods used and the data collected.

* * *

PROJECT JUSTIFICATION IN A MULTIPRODUCT CHEMICAL PLANT*

By

Andrew Tsu-chao Chang
American Cyanamid Company

Two of the major characteristics of the chemical industry -- widespread competition and a keen interest in research -- result in a rapid evolution of technology. This rapid technological progress does not necessarily mean that products are rapidly rendered obsolete, but rather that the processes and procedures by which products are made are subject to change. Often it takes years to create and develop successful new chemicals and processes; but once new chemicals and methods are launched, they are subject to change overnight. This rapid and sudden advance in technology causes a high rate of obsolescence in the existing equipment and facilities.

The decision to purchase new capital equipment is a long-range commitment. Error in timing can be very expensive. In order to achieve sound and pertinent decisions, management must fully understand the nature of the problems existing in equipment replacement. This article will discuss the reasons for equipment acquisition and replacement in the chemical industry, and present the method used by a large dye and pharmaceutical plant, of a leading chemical company, in the economic justification of projects involving large sums of money.

TYPE OF EQUIPMENT

Many different types of equipment are used in the chemical

*The material used for this article was obtained by the author while working for his doctoral degree at the Illinois Institute of Technology under the guidance of Professor Gerald J. Matchett. A companion article, "Management's Yardsticks of Project Justification in the Chemical Industry", will appear in a later issue.

industry. Functionally, though, they can be grouped into two major categories: operating and non-operating equipment. The operating equipment which is used to produce the product is composed of such units as storage tanks to store materials, conveyors and pumps to transport materials, kettles to mix and combine materials, filter presses to separate solids from liquids, blenders to mingle materials, etc. The non-operating equipment, which is used to facilitate plant operation but is not directly used to make the product, consists of boiler-house equipment, laboratory equipment, service equipment, and office equipment. Since the non-operating equipment can often be found in many other industries, the following discussion of capital-investment justification will concentrate on the operating equipment so that the special feature of equipment replacement in chemical industry can be isolated and elucidated.

REASONS FOR ADDITIONAL CAPITAL INVESTMENT

It is unlikely that any chemical company will invest capital merely to increase sales without corresponding profit increases. Additional capital investment required on the operating equipment for adding or maintaining profits in the chemical industry can result from any one or a combination of the following reasons: (1) operational necessity; (2) expansion of existing venture; (3) process changes; and (4) new ventures.

Operational Necessity

The replacement of equipment in the industry occurs most frequently because of operational necessity. In the chemical plant every product made goes through a series of units. For example: liquid raw material is continuously transferred into a feed tank from a supply tank; it is then pumped through a heat exchanger, super-heater and converter, and finally emerges from a distillation column as the final product. Thus it is obvious that a breakdown of any piece of equipment in the series will stop the whole process.

Regardless of satisfactory preventive maintenance on the

equipment, it can be expected that certain components of plant units, such as heat exchangers, pumps, kettles, autoclaves, and tubs, will eventually wear out. These pieces of equipment could be used in a standardized operation for making products. They must be either repaired or replaced.

The replacement of a piece of existing equipment has three possible outcomes. The first is a direct replacement of the existing unit with an exact duplication of the unit. The second is the replacement with standard units of fixed design, a category which includes such items as pumps, blowers, driers, compressors, and electric motors, where rigid performance specifications exist but where there is considerable freedom of choice as to make and vendor. The third is the replacement of an existing item with a new design which is affected by data obtained by technical and maintenance personnel, as, for instance, when corrosion studies made by the metallurgist show that one type of construction material is more desirable than another under actual operating conditions.

Expansion

An actual increase in product demand or an expected upward trend of sales of an existing product, indicated by the market-research group, could result in plant expansion, providing the capacity of the existing equipment is inadequate to handle the actual or expected additional volume. Expansion tends to maintain the existing vendor-vendee relationship. Without the expansion, it is possible that the vendees would place their orders elsewhere to minimize the red tape and expenses resulting from splitting orders to a number of suppliers. On the other hand, expansion of the existing equipment at the strategic moment would have the advantage of capturing a larger share of the early market, where other suppliers have lagged behind.

The number of pieces of equipment required for expansion is dependent upon the expected volume of the future sales and the characteristics of the process. The simplest expansion is to replace a smaller-size tool with a larger-capacity tool, when

the former is unsatisfactorily fitted to handle the expected volume.

The second type of expansion is the addition of another piece of the limiting tool to the operating unit.[1] Product A, for instance, is made in batches through a series of tools including chlorinator, clarification press, precipitation kettle and centrifuge. The individual tool cycles, in making a batch of this product, are assumed and shown as follows:

Tool	Cycle Time	Maximum Batches Made/Day[2]
Chlorinator	24 hours	1
Clarification press	4 hours	6
Precipitation kettle	12 hours	2
Centrifuge	6 hours	4

Since the chlorinator is the limiting tool and has the longest cycle, i.e., 24 hours per batch, the maximum number of batches that can be made by this unit will be one batch per day, regardless of how many batches the others can process. Thus, addition of another chlorinator will double the capacity of the unit. In other words, two chlorinators can be scheduled to finish a batch every 12 hours.

The third type of expansion covers duplication of the existing tools or the modification of the existing unit by the addition of a number of tools. In general, this type of expansion requires a large sum of capital investment, as compared with the other two types.

Process Change

As stated previously, an outstanding characteristic of the chemical industry is the strong competition among producers. In

[1]The limiting tool of any operating unit is the tool which has the longest processing cycle.

[2]Number of hours per day divided by the cycle time of the tool.

order for a chemical plant to survive in business, its product line must be improved in quality and reduced in cost. New, better, and cheaper processes must displace the old. Any drastic change in process would probably result in either the alteration of existing equipment or the addition of new pieces, depending upon the versatility and the capacity of the existing tools. The net result is usually savings in labor, materials, and maintenance, and improvement in the quality of the product.

Process changes which result in an additional investment in equipment can also be initiated through other factors, such as the improvement of working conditions, safety requirements, and industrial hygiene.

New Ventures

Literally speaking, the chemical industry has been built and expanded through research. The research teams of the leading chemical companies are continuously striving for new products, new processes, more efficient techniques, and better performance from already satisfactory products. In the case of a new product which has been developed in the research laboratory and successfully produced in a pilot plant, and which exhibits good market potentiality, management must determine the facilities required for commercial-scale production. Consideration is first given to the availability and utility of existing equipment in the plant.

The situation is always simplified when the new product can be made by and fitted into the schedule of the existing equipment. However, this is seldom the case. In order to pursue the new venture, a capital investment usually must be made in new equipment. This type of venture is directed toward expansion of the plant business beyond that expected from the growth of previously established products.

METHOD OF MAKING ECONOMIC JUSTIFICATION

So far, the general reasons for the replacement of operating equipment have been discussed. There still remains a question as to whether the capital expenditure involved can be economically

justified, inherently and in competition with other projects under consideration, assuming that funds available for any one are not a limiting factor.

Various techniques are available to the management. The technique used at the ABC chemical plant for evaluating the economic justification of a project varies with the amount of investment involved, the complexity of the project, and the authority required for approving the request. In general, projects having an estimated cost over certain dollar limits, and requiring the approval of the Budget Committee of the company, are handled by the widely-known "payout time".

PAYOUT TIME

The payout time, as its name implies, expresses profitability as the number of years required to recover depreciable fixed investment from depreciation accruals and profit after taxes. For example, if the installation cost of a proposed vacuum packer is $100,000, the write-off period is ten years, and savings after taxes resulting from the new installation are estimated at $15,000 per year, the payout time will be equal to

$$\frac{\$100,000}{\frac{\$100,000}{10} + \$15,000} = 4 \text{ years}$$

Note that in the above calculation the $10,000 write-off is added back to the $15,000 net savings to arrive at the payout period. This is done because, in arriving at the net savings, the $10,000 had previously been subtracted.

If the depreciation period is reduced from ten years to five years, and savings after taxes are increased from $15,000 to $30,000 per year, the new payout time will be two years.

CRITERIA

In order to derive the payout time, certain data must be accumulated. The following data are used in the ABC plant for the calculation:

(1) New capital required
(2) Working capital
(3) Estimated annual sales
(4) Sales, advertising and promotion expenses
(5) Gross profit
(6) New profit after taxes
(7) Return on total investment
(8) Payout time on new investment
(9) Payout time on total investment

ECONOMIC JUSTIFICATION STUDY

For those projects which are estimated over certain dollar limits, the Economic Justification Data, including both the detailed and summary form, must be prepared and presented to the Budget Committee for scrutiny. The Economic-Justification-Data analysis form provides for the computation of the payout time for the project. The results, of course, do not necessarily mean that the proposed project will be accepted. The subsequent portion of this article will illustrate the way in which those criteria mentioned above find their way into the economic-justification studies.

The Preparation of the Detailed Economic Justification Data

The detailed Economic Justification Data include three estimates: the estimate of the proportionate value of existing property to be used; the estimate of working capital required; and the estimate of operating results from the investment.

The proportionate value of existing facilities to be included in the gross investment is the sum of the following six items: idle building space, idle equipment, transferred equipment, intermediate production facilities, utilities, and general services.

The proportionate value of idle building space used in the new project is determined as a certain percentage of the original acquisition cost of the building. This percentage is the ratio between the number of square feet of the idle building space used for the new project and the total area of the building. For instance, the initial acquisition cost of a

building is $100,000 and has a total working area of 8,000 square feet. Some 2,000 square feet have been left idle and will be used for the new project. The proportionate value of the idle building space will be

$$\$100,000 \times \$2,000/8,000 = \$25,000$$

The idle equipment consists of those tools which are installed but, due to various reasons such as product or process obsolescence, remain idle in the plant. For a proposed project which involves the re-use of this equipment, value added to the new project is the original acquisition cost of the idle equipment.

The transferred equipment can be classified into three categories. They are: (1) those items which have been used in the existing operation and can be used for the proposed project; (2) those which were bought for stock; and (3) those which were used and have been reconditioned. For transferred equipment in the first category, the original installation cost is used as the proportionate value for the new project. For the second category, the original acquisition cost is used. For the third category, the reconditioning cost is used.

The book value is not considered in the estimation of proportionate value of the idle equipment and transfer equipment. There are two reasons for this: (1) the group depreciation practice at the ABC plant considers all equipment in a shop as a group, and (2) the omission of book value leads to greater simplicity.

The intermediate production facilities are used in shop operations but are not directly used for making the product. This type of equipment includes refrigeration units, exhaust systems, effluent units, and safety showers. The utilities include the electric system, river-water system, well-water system, and the steam and power system. The general services include such things as laundry service, maintenance service, yard service, and shipping service.

The computation of the proportionate values of these three

categories is based on factors derived by the Accounting Department. Biannually, the Accounting Department reviews and allocates the total costs of these three categories to the operating department based on the product investment made in each department. For instance, assuming the general service cost for the first six months of the fiscal year to be $500,000 and the product investment made in Department Y to be $2,000,000, a figure amounting to one-tenth of the total product investment of the plant, the general service cost allocated to the Department Y during this period will be

$$\$500,000 \times 1/10 = \$50,000$$

This $50,000 divided by the product investment of $2,000,000 gives a factor of 2.5% per dollar investment for the Department Y. This factor is then used for computing the appropriate value of general service on any new capital investment made in this department for the ensuing six-month period. For example, if the new investment is $1,000,000, then the proportionate value of the general service charged to the new project will be

$$\$1,000,000 \times 2.5\% = \$25,000$$

The accounts receivable, and inventories required in raw materials, work in process, finished products, and supplies, are considered as the working capital of the ABC plant.

Accounts receivable are estimated at ten percent of the expected sales value. The cost value of estimated inventories is based on the number-of-months' supply required. In the case of expansion, a monthly average is derived based on the investment in the product during the preceding twelve-month period. This monthly average times the percent expansion of the existing capacity gives the estimated inventories required. For a new venture, a three-months' inventory amounting to one-fourth of the estimated annual cost of production is used.

The estimated operating results of a proposed project show its expected net income after taxes for a period of ten years.

The reasons for limiting the period to ten years are that the average service life of the operating equipment is expected to be approximately ten years and sales forecasts become even more difficult for longer periods.

The estimate of operating results is the joint effort of the Accounting, Purchasing, Sales, Market Research, Production, and Engineering Departments, and research personnel.

The actual total estimate includes estimates of yearly sales, cost of sales, and expenses for the subsequent five years. The figures used for the fifth year generally are used as the average sales for the sixth to the tenth year inclusive. This figure is used because the new project is expected to reach a normal operating condition at the end of the fifth year.

The sales estimate includes only estimated new or replacement sales to outside buyers, and does not include transfers to other plants within the company. The dollar value assigned to the estimated sales is based on the expected capacity of the equipment operated, the unit produced, and the price per unit. The expected operating capacity is the estimated percentage of normal rated capacity at which the facility is expected to operate over a year, to produce estimated sales for customers and/or transfers to other plants. The unit produced is controlled by the expected operating capacity. The total dollar sales are the product of the total number of units produced for sales, and the price per unit.

In addition to the usual items of labor, materials and supplies, and overhead (cost items which fluctuate more or less with the volume of output), the cost-of-sales estimate includes two relatively fixed components: (1) the depreciation on new facilities and (2) the depreciation on existing facilities to be used for the new project. For the former, no predetermined rate is set for the depreciation. The degree of risk involved, the stability of the product, market potentials, and the competitive situation are usually weighed before the decision is made. For the latter, a rate of ten percent is often used. However, a faster rate could also be applied. The condition of the existing

facilities is the major consideration.

After the total cost of sales have thus been determined, the cost is deducted from income from total sales, to determine the gross profit figure.

Savings on existing business could be due to the use of a portion of production to replace material now purchased, or processing-cost reductions due to new equipment. Penalty on existing business could result from discontinuing the production of a product because of the installation of the new equipment. The usual result is some degree of idle equipment. The estimate of savings or of penalty on existing business rests on the judgment of the person who prepares the Economic Justification Data.

The gross profit derived from the difference between sales and costs of sales, plus or minus the savings or penalty on existing business, will give the profit on sales.

Other expenses include four major classes of expense: commercial expense; administrative expense; research and development expense; and royalty expense.

The commercial expense consists of selling, advertising and warehousing costs. It is estimated as a percentage of the expected sales, and varies with the project. For instance, the percentage figure used for new ventures that ordinarily require a great deal of advertising and sales promotion could be higher than that used for products already having a steady market.

The administrative expense is also based on a percentage of sales. The research and development expense includes only the future expenditures which were not included as product development on the cost-estimate sheet[3]. This expense could result from future research aimed at improving the quality and yield of

[3]The cost estimate sheet gives the total estimated cost including labor and material costs, engineering-service and mechanical-service charges, cost of dismantling, and the transferred-plant values.

a product, widening the application of the product, and effecting process inprovement. There is no set pattern for guiding the estimation of this expense. The circumstances of each individual case determine the basis for estimation.

Royalty expense is involved only when a product or process was developed and patented by another party. It is usually estimated as a percentage of sales.

The sum of the commercial expense, the administrative expense, the research and development expense, and the royalty expense, deducted from the profit on sales, will give the net income of the project before taxes.

A predetermined tax rate is used for all projects and depends, of course, on the tax policy established by the government. The present rate is fifty percent of the net income before taxes. This amount is then deducted to determine net income after taxes.

The Preparation of the Summarized Economic Justification Data

From information accumulated on the detailed Economic-Justification-Data form and the cost-estimate sheet, the summarized Economic-Justification-Data sheet is prepared. The summarized-data sheet involves four parts: (1) estimated capital requirements; (2) estimated sales and profits; (3) payout time on new capital required; and (4) payout time on total capital required.

The estimate of capital requirements consists of the estimate of new capital required and the estimate of total capital required. The former includes new fixed capital, expense items, and pre-plant costs. The latter, in addition to the new capital required, includes the proportionate value of existing facilities to be used and the working capital.

The new fixed capital represents new money required for the new fixed facilities, such as the cost of purchasing tanks, kettles, compressors, and pumps.

The expense items represent new money of an expense nature, required in connection with new fixed facilities, such as the labor and material costs involved in the dismantlement of old facilities, the transfer of idle equipment, and the re-arrangement of the

existing pipelines.

The pre-plant costs represent those costs incurred between the time the project is authorized and the time commercial operations begin. They include such items as training new personnel for the job, the cost of running-water batches, and and sales promotion.

The proportionate value of existing facilities to be used and the working capital required are taken directly from the detailed Economic Justification Data.

Based on the information accumulated on the detailed Economic-Justification-Data form, the estimated-sales-and-profits section provides seven columns for summarizing the operating results for subsequent five-year periods. An annual average for the second five-year period and a total for ten years are also given.

The first column shows the year of operation. The second and the third columns show the dollar figures of annual new or replacement sales and the anticipated levels of output as a percent of capacity. The fourth column shows the amount of depreciation on new fixed capital. The fifth through the seventh columns show the amount of new profit after taxes and depreciation, the net profit after taxes and depreciation as a percentage of sales, and the net profit after taxes and depreciation as percentage of total capital required.

The payout time on new capital required is the number of years needed for recovering the new capital investment. In other words, it is the number of years for which the aggregate of the depreciation on new fixed capital and net profit after taxes and depreciation equals the new capital investment. For example, for a given project let us assume that the new capital required is $1,000,000 and that the total capital required is $1,250,000. The estimated depreciation on new fixed facilities and the new profit after taxes and depreciation may be shown as in the table on page 26, in which the payout time for the project lies somewhere between two and three years, and the exact payout time can be calculated by interpolation. The exact payout time is equal to:

$$2 \text{ years} + \frac{\$1,000,000 - \$650,000}{\$400,000} \text{ year}$$

$$= 2.9 \text{ years}$$

Year of Operation	Depreciation on New Fixed Facilities (1)	Net Profit After Taxes and Depreciation (2)	Aggregate of Columns (1) and (2)	Accumulated Total to Date
1	$100,000	$200,000	$300,000	$ 300,000
2	100,000	250,000	350,000	650,000
3	100,000	300,000	400,000	1,050,000
4	100,000	350,000	450,000	1,500,000
5	100,000	400,000	500,000	2,000,000
Annual Average for Next 5 Years	100,000	400,000	500,000	
Total for Ten Years	1,000,000	3,500,000	4,500,000	

If the value of existing facilities to be used in new projects is twenty percent or more of the total capital required, the payout time on total capital required is calculated. This payout is the number of years for which the aggregate of the depreciation on new fixed capital,and net profit after taxes and depreciation on the existing facilities,equal the total capital required. Given the previous example, and assuming further that the existing facilities are depreciated at a rate of ten percent per year, a new table may be constructed as follows:

Year of Operation	Aggregate of Columns (1) and (2) in Previous Table (A)	Depreciation on Existing Facilities to Be Used (B)	Aggregate of Columns (A) and (B)	Accumulated Total to Date
1	$300,000	$25,000	$325,000	$ 325,000
2	350,000	25,000	375,000	700,000
3	400,000	25,000	425,000	1,125,000
4	450,000	25,000	475,000	1,600,000
5	500,000	25,000	525,000	2,125,000

The payout time on total capital required lies somewhere between the third and the fourth year and can be calculated as follows:

$$3 \text{ years} + \frac{\$1,250,000 - \$1,125,000}{\$475,000} \text{ year}$$

$$= 3.3 \text{ years}$$

COMMENTS

It is necessary to state here that a short payout time does not guarantee the approval of the project by the management. There are other general factors which influence the final decision. These general factors will be discussed in a forthcoming article.

It should also be mentioned here that no attempt was made to evaluate the technique used by the ABC chemical plant. Nevertheless, it is hoped that this article will encourage other individuals to make similar investigations of the practices of competing companies in chemical or other industries. A series of these presentations would very likely be of value to both theorists and practitioners in this area of business management. Furthermore, there is reason to believe that management might find that an examination of the practices

presented in this area of decision making may provide them with guides to the formulation of a sounder technique for their organizations.

* * *

BACK ISSUES

The available back issues of THE ENGINEERING ECONOMIST are Volume 4, Numbers 3 and 4 , Volume 5, Number 1, and (in very limited supply) Volume 2, Number 2 and Volume 3, Numbers 1, 3 and 4.

Because of the many requests received for back issues, an arrangement has been made for microfilming of the back files. Positive copies will be obtainable, early in 1960, from University Microfilms, Inc., 313 N. First Street, Ann Arbor, Michigan.

"INDUSTRY AND TECHNICAL PROGRESS"*

A Book Review

By

John H. Norton
E. I. du Pont de Nemours & Company

The problem of speeding up the application of new scientific and technical knowledge in industry is not new. The appearance of another book on this subject is, therefore, not unusual. It is unusual, however, to find a book which covers the subject as thoroughly and as interestingly as the book under review.

Although it is addressed to the particular problems of British industry, the book is well worth study by Americans interested in this topic. One reason is that there are many similarities between British and American industries; thus, many common problems. Another reason is that this book deals with some of the special problems faced by industries which must compete in world markets for their growth and prosperity. If British industry progresses, it must do so in the face of competition from many countries, including two (the United States and Russia) with greater facilities for producing technically trained personnel and more heavily endowed with natural resources. The struggle of British industry to progress in this environment should be of increasing interest to American industrialists, in view of growing competition to them from Soviet industry.

It is not however, a book which will be rewarding to those who are seeking information about specific techniques. There are, for example, no details on the criteria British firms use in making investment decisions. Likewise, there are no details regarding methods used for depreciation accounting. These subjects, like many others, are covered only in regard to their general

* C. F. CARTER and B. R. WILLIAMS: Oxford University Press, London, 1957. New York Price $4.00. 254 pp.

effect on the speed of application of science.

The task undertaken by the authors was to report the findings of a special Science and Industry Committee in regard to these objectives:

> "To identify those factors which determine, in different industries and in different types of firm, the speed of application of new scientific and technical knowledge; to examine their relative importance, their interrelations, and their correlation with characteristics of the firm or industry; and to obtain evidence of the effectiveness of measures already taken to speed up the application of science in industry, or to remove hindrances to such application."

This was only the first part of the Committee's assignment, and the book under review was the initial report. Other reports were to follow on "material which would contribute to knowledge of ... investment decisions", and "factors influencing innovation". The second report, on Investment in Innovation, will be reviewed in a forthcoming issue of The Engineering Economist.

Although not formally divided by the authors, the report falls into four sections. The first (Chapters 1 and 2) deals with the formulation of the Committee and its preliminary survey of the problem area. The second (Chapters 3 to 15) describes the detailed studies in specific subjects. This section deals with the various problems of getting research results, communicating these results to industry, and applying them effectively. It reports findings regarding the effect of such factors as: the supply of trained personnel; the availability of money; organizational structure; investment and depreciation policy; attitude of management; industrial environment; market characteristics; and the structure of taxation. The third section (Chapters 16 and 17) summarizes the entire effort and presents the Committee's findings as they apply, first, to individual firms, and, second, to the British economy. The fourth section (Appendices I - III) acknowledges the contributions of others and presents data regarding the 152 case studies used as a basis

for the conclusions. Four interesting examples from the case studies are described in some detail.

It is suggested that those who are interested only in the summary and conclusions start with Appendix I and follow with Chapters 16 and 17. There, the authors have listed (pp. 178-183) the twenty-four characteristics the Committee found to be related to technical progressiveness. Quoting from page 178:

> "The significant outcome is that there are twenty-four characteristics which are not only (by definition) present in (technically) progressive firms, but also prove to be generally absent in un-progressive firms."

Of the twenty-four, seven, all relating to the "quality" of management, were thought to be the most fundamental (p. 188):

(1) A sound policy of recruitment of management.

(2) An ability to attract talented people.

(3) A willingness to arrange for the effective training of staff.

(4) High quality in the chief executive(s).

(5) Good quality in intermediate management.

(6) An ability to bring the best out of managers.

(7) Use of scientists and technologists on the Board of Directors.

These seven "qualities of management" were placed ahead of such factors as the rapid replacement of machines, and the use of management techniques (work measurement, production planning and control, etc.), although these characteristics were in the list of twenty-four.

It is interesting to note that the Committee concluded that depreciation allowances (whether or not in an inflationary period) were not a major factor in determining replacement policy (p. 151), and also found that only 13 of 150 firms in the general sample had an explicit financial criterion for investment decisions

(p. 82). It was concluded, however, that certain aspects of taxation, particularly inheritance taxes, could have substantial influence on the speed with which new ideas were adopted in some firms (p. 152).

It is also interesting to find that the American educational system is, for once, held up as a comparative model of efficiency in producing technically trained personnel. In commenting on the inadequate supply of such personnel in Britain, the authors conclude that a main problem is the substantial loss of children, suited to scientific and technological work, to other fields. The authors feel that much of this wastage can be avoided and suggest several approaches. One is in regard to the educational system itself: "Comparison with other countries shows that familiar features of the British education system are not elsewhere found necessary; for instance, both Russia and the United States manage to do without much specialization in their schools" (p. 95). A second approach is to imitate the United States in her success in having "attached the social prestige of a first university degree to a level of attainment capable of being reached by greater numbers of students ... " (p. 99).

Education is one of the key points in the concluding chapter (Chapter 17, "A Progressive Economy"). The authors stress that if Britain is to consolidate her industrial research and apply the results effectively, she will have to meet a much larger demand for scientists and technologists. This, the authors point out, will be very difficult to accomplish "without considerable changes in the educational system".

It is unfortunate that the authors are not able to follow this statement with succinct advice on just what the desired changes are or how they can be brought about.

* * *

"HOW TO ADMINISTER CAPITAL SPENDING"*

A Review Article

By

Earl E. R. Jones
Craig, Dunmire & Associates and Stanford University

The calculations required to establish prospective rates of return for alternative capital expenditures, the ranking of proposals according to their merits and relative risks, and the selection of most appropriate proposals have all been the subject of numerous articles. Too little attention has been paid, however, to the more general question of how the results of the foregoing efforts may be made genuinely effective in the business enterprise. In his article "How to Administer Capital Spending", Professor Matthews has made a worthy contribution to the literature by backing away from the specifics of computational technique and taking a long look at how this tool may be integrated most effectively into an organization made up of people -- people whose goals, methods, and knowledge differ from one to another and from time to time. Only by providing common objectives and values and by establishing adequate control and review can the heterogeneity which constitutes even the modest-size enterprise be brought into clear focus, integrated, and made most effective.

The author reports upon capital-investment practices in 50 companies which he studied. He traces the entire capital-spending process from the sources of ideas through the stages of planning and budgeting, decision making, the fixing of responsibility and authority, explaining and convincing, and the important follow-up. He comments on the validity of many of these practices and suggests a number which he feels are most worthwhile.

The planning "guide lines" idea described by Professor

* JOHN R. MATTHEWS: Harvard Business Review, Volume 37, Number 2, March-April 1959, pp. 87-99.

Matthews should provide food for thought, especially among the play-it-by-ear school. One can conceive of guide lines as a set of projected limits representing the highest and lowest operating levels to be reasonably expected within the forecast period. This is the plan set by top management. Within these limits is the essential flexibility with which members of middle management can learn to exercise their judgments and skills in the establishment and carrying out of shorter-range plans necessary to the regular operation of the business. Moreover, departments and divisions, armed with knowledge of the plan, may employ comparable standards and be guided toward a common goal. Such a procedure permits managerial attention to be directed less toward the routine and more toward the unexpected. If the play-it-by-ear school really wants flexibility, here it is: freedom to devote a maximum of attention toward new issues while permitting informed subordinates to carry on much more of the day-to-day operation. It seems hardly worthy of comment that capital expenditures made without clear knowledge of the company's plans and expectations, viz., the guide lines, may represent little more than the building of one's house upon the sands. Yet the author cites examples from his study which show that just such errors are being made, some with very unfortunate consequences.

Basically, the guide-line idea is not a new one, for it underlies the concept of the flexible budget, long an effective tool in the kit of alert management. Nonetheless, since many businesses fail to employ the technique as a planning device, the stress given it by Professor Matthews seems amply justified. Moreover, his emphasis upon passing the planning information along for the active use of the more junior levels of management is unquestionably sound. Among these men are to be found the top executives of the future. How much better to give them the opportunity of developing their planning and coordinating skills now than to wait until they are already in top positions before permitting them to make the mistakes which are inevitable in the learning process. Clearly, the business can but profit from the systematic and more gradual development of managerial talent

inherent in the former approach.

The principles of budgeting have been so thoroughly tested in practice and discussed in the literature as to leave no doubt concerning their merit and essential nature. Yet the author reports that even among some of the large firms which he studied, capital budgets are not universally employed. We are aware that the same is true of many smaller manufacturers. It must be emphasized that investment in capital equipment is relatively inflexible and long-lived by its very nature. It is therefore deserving of considerably more analysis than is usually afforded it. For example, one of the chief problems encountered by businesses in financial difficulty is the lack of planning in the allotment of funds. As a result, so much is spent on fixed and semi-fixed assets that there is too little left with which to buy materials, meet payrolls and the like. In short, there is insufficient working capital. Careful planning and budgeting of capital expenditures will go a long way toward eliminating this source of difficulty.

Just who should be in charge of decision making for capital spending is a topic on which Professor Matthews reports significant differences of opinion. It is suggested in his paper that the company's financial officer might be the best one to head up this important function. There seems little doubt but that this is often true. I hasten to point out, however, that it is the manner in which the decisions are made rather than who does it that is the key here. It is true that financial personnel are frequently more aware of the company's responsibility to its owners than their production and sales counterparts, but this does not, per se, single out the finance department as being either omniscient or necessarily correct in its method of analysis. New undertakings must embrace contributions from sales, finance, production, and other affected departments. Once the best judgments of these groups are available, the lot must be integrated into a meaningful whole and a decision made. The technique employed in the integration must not of itself introduce new judgments or permit the drawing of conclusions which are

contrary to the best interests of the business.

It is apparent that Professor Matthews deliberately limited the scope of his article to exclude techniques of evaluating the relative merits of proposed capital expenditures, i.e., decision making. The ample coverage of these techniques elsewhere in the literature tends to justify the omission (see following footnotes). It is nonetheless regrettable that Professor Matthews chose not to comment upon those which he did find in use. Of particular interest would have been an analysis and evaluation of the results deriving from existing practice as he found it. However, the scope and importance of this contribution as a whole would seem to outweigh possible criticism in this respect.

One of the most written-about topics of the day is just how one employs responsible estimates of future receipts and disbursements to represent reliably the relative merits of one or more alternative proposals, preparatory to selecting the best from among them. There are a dozen or more methods for making such a decision. Each has its advocates and each, its opponents. A survey of the practices quickly evidences two camps. One favors simplicity of calculation at all costs. The other, and more sophisticated of the two, considers accuracy, within the limits of the forecasts, as being of sufficient import to justify a method which recognizes that a dollar in hand now is worth more than the promise of a dollar at some specified time in the future. Inflation aside for the moment (though in a sense it lends strength to our argument), a thousand dollars in hand is worth perhaps $30 to $70 (or a greater amount) more than if received a year from now. It is evident that the investment of today's $1,000 will bring to its owner interest or earnings of $30 to $70 or more during the intervening year. Any method of analysis which fails to take into account this time value of money is simply inadequate.

It has been clearly demonstrated by a number of writers that wrong decisions can be and are made daily regarding the expenditures of capital funds when the "easy" methods of computing rate of return are employed. One is a bit taken aback when he ponders the large sums which are spent for capital goods upon

the strength of analyses which at best can only approach correct results and at worst can (and often do) lead to decisions exactly opposite from the correct ones. Some of the literature establishing the facts of this situation is cited in Footnote 1.

It seems the more remarkable when one realizes that just a little more time devoted to the proper approach can yield a result worthy of the reasoned estimates made by responsible executives. It would appear all but insulting to their judgment that the "easy" methods should be employed. As has been pointed out by Reul,[2] the "complexities" of calculation based upon the time-value-of-money concept can be learned by a competent person having no more than a high-school background in mathematics. Avoidance of the correct methods on the strength of their "complicated" methematics then seems a weak argument indeed.

Finally, the performance review offers an opportunity to exercise 20-20 hindsight. Of course it will turn up errors in judgment; that's what it's for. On the other hand, any executive worth his salt will recall numerous errors which he has made in the process of gaining his experience. Despite our best efforts, the fact is that mistakes are going to be made now and then, but this is a poor excuse for hiding one's head in the sand and hoping for the best. How much more quickly one can learn what to avoid in the future if he has the errors of the past brought

[1] Alan G. Bates and James B. Weaver: "Your Next Capital Venture", Chemical Week, June 15, 1957, pp. 115-47.

Joel Dean: "Measuring the Productivity of Capital", Harvard Business Review, Vol. 32, No. 1, January-February 1954, pp. 120-30.

Eugene L. Grant: Principles of Engineering Economy. The Ronald Press Company, New York, 1950.

M. E. Salveson: "Long-Range Planning in Technical Industries", The Journal of Industrial Engineering, September-October 1959.

George Terborgh: Dynamic Equipment Policy. The McGraw-Hill Book Company, New York, 1949.

[2] Ray I. Reul: "Profitability Index for Investments", Harvard Business Review, Vol. 35, No. 4, July-August 1957, pp. 116-32.

to his attention rapidly and in specific, concrete terms! The best means of providing this information is the performance review. Is capital spending any less deserving of periodic review than inventory, materials, or labor costs? Indeed, it would appear the more so because of the long lives and inflexibility of investments in fixed assets.

As pointed out by Professor Matthews, many firms consider the profit-and-loss statement as an adequate means of evaluating capital-spending policy. Few ideas could be farther from accurate. Though there is nothing which would serve as a simple substitute for the profit-and-loss statement, one must recognize its many shortcomings. Consider the effects of inventory policy (LIFO, FIFO, cost or market); of estimated asset lives which determine depreciation rates and of the depreciation method itself (straight-line, double-declining-balance, sum-of-years-digits); of maintenance and other expenses; of labor and labor rates; of the cost of borrowed money; of changing tax rates; overhead allocation; and so forth. Each of these affects the statement profits. Thus to use the P & L statement as a means of measuring the profitability of capital expenditures is clearly illusory. Firstly, it embodies too many variables to be effective in assessing the influence of any one of them. Secondly, by the time we determine the accuracy of and make adjustments in, the P & L statement, we will have lost many opportunities to apply the lessons which would have been learned from a scheduled review of asset performance.[1]

The only meaningful evaluation of asset profitability arises from an analysis of the marginal effect upon the receipts and disbursements of the business resulting from the use of the asset. Forecasting provides the educated guesses about the results of

[1] Consider the case of an asset whose expected service life is ten years but whose product is technologically obsolete in four years. If the asset cannot be put to profitable use for its remaining life, the firm's profits were clearly overstated for the four years.

installing a machine, but only the performance review will tell us if our guesses were correct, or if and where we erred. In this way we can profit most quickly by experience. Without such a tool, the evaluation of past judgments -- good or bad -- may be a long time in coming. Failure to profit from lessons which might have been learned from performance reviews can but compound the problem.

Professor Matthews has backed off and taken a long look at capital-spending practices. Leaving the specific techniques of decision making to the many writers on the subject, he has shown how the over-all process of reasoned capital spending may be integrated into the business organization and made to produce favorable results.

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"ULTIMATE COST OF BUILDING WALLS"*

A Review

By

John E. Ullmann
Stevens Institute of Technology

The great increase in technical alternatives requires the development of accurate analytical methods, relating alternative costs to the unit of performance. The present work is an excellent contribution to the growing literature on this subject. It enables the structural engineer or architect to evaluate the costs per square foot of wall, using any desired wall system and taking into account all the variables which affect ultimate cost. The analysis follows conventional present-worth methods, since it is clearly necessary to relate a succession of future payments such as maintenance, taxes, heating, insurance, etc., to a present investment.

The monograph is based on New York prices but should be easily adaptable to other conditions. It derives its original data from experiences in the New York building boom following World War II. Skyscrapers are still being constructed in considerable numbers and, as has often been pointed out, the total office floor space added in New York since 1948 is greater than all the available space in Chicago (the second largest aggregation). Some architects bemoan what they consider the uniformity of these buildings, but actually the planners have exercised desperate ingenuity in the search for something different in the wall appearance. Basically, the buildings follow the steel-frame-plus-curtain-wall design. The problem dealt with in the book is mainly that of choice among the curtain-wall materials.

* CLAYFORD T. GRIMM and JAMES G. GROSS: Structural Clay Products Institute, Washington, D. C., 1958. 36 pp. Obtainable without cost from the Structural Clay Products Institute, 1520 Eighteenth Street, N. W., Washington 6, D. C. A.I.A. File No. U6.

These materials include masonry, glazed brick, aluminum, gold anodized aluminum, colored concrete, stainless steel, structural glass, heat-absorbent glass, etc., and, according to the authors, range in price from $2.60 a square foot to $32.00 a square foot. A way of economic analysis is clearly needed here, since all these alternatives have been used, in the buildings listed by the authors.

The method proposed here,for which ample tables, charts, work-sheet designs, etc., are given, relates a number of future cost factors to the initial investment. These cost factors include the value of money and depreciation laws, which are, of course, hard to predict over the future life of a building. Six per cent is assumed here. In addition one can allow for increases due to price changes, in the annual or other future expenditures.

An important feature is the distinction between tax-exempt and taxable owners of the building. In the former case, there are no tax cash credits as there are when depreciation allowances may be deducted from taxable income. Accordingly, a tax-exempt owner will normally be ill-advised to adopt glass walls, for example, with their higher initial cost.

Two minor categories are next discussed: the cost to support the walls and the cost for the space taken by the wall itself. Obviously this argues against thicker walls, but this cost can only be considered where the building occupies all the available property, as on a restricted city site.

Maintenance is the next item, comprising painting, cleaning, pointing and caulking, for which possible schedules are given, including an annual rise of 3.7% in the prices. Heating, air conditioning and illumination are next considered, in the conventional manner, using degree-day data. Air conditioning is, of course, an indispensable consideration, since practically all buildings of the kind discussed here were air-conditioned. With electrical loads sometimes exceeding 12,000 kilovolt amperes, such buildings may be equivalent to substantial industrial plants. Illumination is a moot point, however, since most lights are left on all day anyway, especially where the buildings have

a considerable floor area.

Lastly, the authors deal with real estate taxes -- higher for walls of high initial cost and with insurance, lower for fire resistant walls.

The authors carry out their analysis for brick-cavity, metal-panel, and double-plate-glass walls, and their conclusion is that for a taxable owner, the ultimate cost relatives are 100, 171 and 400; for a tax-exempt owner the spread is even wider -- 100, 172 and 572 (the last for the glass wall). They correctly point out that, in architecture, economics is not the only criterion, but neither is aesthetics.

To a resident or visitor in New York it should be gratifying to note the vast extra sums which have been spent on a little variety in the city's appearance. Whether this argument would impress stockholders, as they contemplate the design of their particular corporate Taj Mahal, is another matter. But then we can ascribe all this to the temper of the times, which increasingly turns social costs into business costs. Even engineering economists, anxious to spread the gospel, have to shut their eyes sometimes, as economics, aesthetics and, last but not least, institutional image-building, continue their perennial battle.

* * *

ERRATA

There are several errors in the Appendix to the article, "The MAPI Urgency Rating", by Myles M. Dryden, which appeared in Volume 5, Number 1 (Summer 1959). With corrections, the Appendix should read as follows:

Let the initial cost of the project be CV_1. Let the stream of earnings over the n years of life be $x_1, x_2, \ldots x_n$. Then the rate of return, r, is defined by:

$$CV_1 = \sum_{k=1}^{n} \frac{x_k}{(1 + r)^k}$$

$$\text{In general } CV_t = \sum_{k=t}^{n} \frac{x_k}{(1 + r)^{k-t+1}}$$

The capital consumption allowance for year t is CC_t, where

$$CC_t = CV_t - CV_{t+1}$$

$$= x_t - rCV_t$$

Specifically, for the first year, the capital consumption allowance is $CC_1 = x_1 - rCV_1$.

Hence, since the U.R. is given by:

$$UR = \frac{x_1 - CC_1}{CV_1}$$, then, substituting the value for CC_1 above we find that the U.R. equals r.

Note also that the sum of the capital consumption allowances over the life of the asset is equal to the initial capital value.

$$\sum_{t=1}^{n} CC_t = \sum_{t=1}^{n} (CV_t - CV_{t+1})$$

$$= CV_1 - CV_2 + CV_2 \ldots + CV_n - CV_{n+1}$$

$$= CV_1, \text{ since } CV_{n+1} \text{ equals zero.}$$

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PART I
AN EXTENSION OF AVAILABLE INTEREST TABLES

By

R. O. Swalm
Syracuse University

Have you ever, when solving for an unknown interest rate, wished for tabled values of interest factors for higher interest rates than those commonly available? Or have you felt the need for tables giving a uniform equivalent, or present worth, of a constantly increasing series of payments? Or for readily available tables for continuous compounding?

Your author has, and therefore was delighted when an opportunity arose to run off such tables on a computer. He is also delighted to have the opportunity to share the results of these computations with others through the medium of The Engineering Economist.

These calculations were performed in the Syracuse University Computing Center, using an IBM 650 machine, and were partially supported by a grant from the National Science Foundation. Lack of space precludes presentation of all of the tables in this one issue of The Engineering Economist; those not appearing here will be published successively in subsequent issues. The tables to be presented are:

1. For Annual Compounding

   a. An extension of Present Worth Factor (Single Payment) tables to interest rates of 100%.

   b. An extension of Capital Recovery Factors to interest rates of 100%.

   c. Gradient Factor, Uniform Equivalent[1] -- for interest rates to 100%.

   d. Gradient Factor, Present Worth[2] -- for interest to 100%.

[1] Yields the uniform equivalent of a series of end-of-period payments starting at zero at the end of the first period and increasing by a constant amount in each succeeding period, when multiplied by the increase in each period.

[2] Yields the "Present Worth" of a series of end-of-period payments starting at zero at the end of the first period and increasing by a constant amount in each succeeding period, when multiplied by the increase in each period.

2. For Continuous Compounding

   a. Present Worth Factor, Single Payment, for interest rates to 100%.

   b. Present Worth Factor -- Constant Stream, for interest rates to 100%.

   c. Gradient Factor, Present Worth,[3] for interest rates to 100%.

Although the original calculations were carried out to eight significant figures, they have been rounded out to four (but not more than four decimal places) since it seems inconceivable that they will ever be used, in engineering economy problems, in conjunction with data of greater accuracy than one part in a thousand.

The increments by which the chosen values of interest rate increased were determined, in part, by the availability of similar tables elsewhere. The increments by which chosen values of time increased were based upon logical considerations.

The inclusion of both continuous and annual compounding tables should not be construed as a reflection of a belief that the choice of an annual or continuous compounding model is a crucial one. It is not difficult to show that either choice results in an imperfect model of almost any real-life situation, and further, it is quite unlikely that a differing conclusion will be reached if an alternate choice is made. Both types of tables are presented here simply because some people prefer one and others the other, and because in some few problems one might be a bit more appropriate than the other.

It should be noted that the tabled interest rates in the continuous compounding tables correspond to equivalent nominal annual rates. The tabled values, therefore, correspond to those found in Gregory's Tables, published by the Atlantic Refining Company.

An excellent case can be made for the use of tabled values

[3] Yields the "Present Worth" of a continuous stream of constantly increasing payments, each payment being a fixed amount greater than the previous payment, when multiplied by the total amount paid in the first year (or, in the case of payments continuing for less than one year, by the total amount that would be paid if the payments did continue for one year at the same rate).

This multiplier is, therefore, one-half the annual rate of increase.

corresponding to effective annual rates. It is understood that tables based on this concept will be presented in the forthcoming revision of Grant's "Principles of Engineering Economy".

It hardly seems necessary to point out to the potential users of these tables that there are many variations in their use (for example, in finding the uniform equivalent of a constantly decreasing series), but it does seem wise to offer an example of the use of each table so that its intended use is clear, and to offer a "derivation" of the equations on which some of the less commonly found tables are based. These follow as Appendices I and II.

In closing, the author would indeed be remiss if he failed to include recognition of his gratitude to his wife and to Mrs. Bernice St. Pierre for their aid in preparing these tables for publication.

APPENDIX I

EXAMPLES OF USE OF TABLES

1. How much can a company afford now in order to prevent an expense of $1000 five years from now, if a before-tax return on investment of 60% is required?

   From the Present Worth Factor, Single Payment Table for Annual Compounding, the Appropriate Factor is 0.0954; therefore the answer is given by $1000 x 0.0954, or $95.40.

2. What annual savings over a 10 year period will justify a present investment of $1000, if the attractive rate of interest is 50%?

   From Capital Recovery Factor, Annual Compounding Table, the Appropriate Factor is 0.5088; therefore the answer is given by $1000 x 0.5088, or $508.80.

3. Maintenance costs on a given piece of equipment are $300 the first year and increase each year by $100. What is the uniform annual equivalent cost of maintenance if this equipment is kept for 5 years? Assume end of year payments, and an interest rate of 20%, compounded annually.

   The maintenance costs can be thought of as in two parts -- a constant amount of $300 a year, and series of payments starting at $100 at the end of the second year and increasing by $100 per year. The

Gradient Factor-Uniform Equivalent gives the uniform annual equivalent (starting at the end of the first year) of such series. The Appropriate Factor (for 5 years and 20%) is 1.640; therefore the uniform annual equivalent of the increasing series is \$100 x 1.640, or \$164.00. The total uniform annual equivalent of maintenance costs is this plus the constant amount (equal to the first year maintenance cost) of \$300, or a total of \$464.00 per year.

4. What is the Present Worth of the maintenance costs of example 3?

As before, the problem must be divided into two parts, and the solution to each added.

a. What is the Present Worth of a series of 5 end-of-year payments of \$300?

b. What is the Present Worth of \$100 at the end of the second year, \$200 at the end of the third, \$300 at the end of the fourth, \$400 at the end of the fifth?

Part a is solved by using the reciprocal of the appropriate capital recovery factor, or

$$\$300 \times \frac{1}{.3344} = \$897.10$$

Part b is solved by multiplying the annual rate of increase, or \$100, by the Gradient Factor, Present Worth for 5 years, 20%, or 4.906, giving \$490.60.

The total Present Worth of maintenance is then the sum of \$897.10 and \$490.60, or \$1387.70.

5. What is the Present Worth of \$1000 ten months hence, if interest rate is 100% per year, compounded continuously.

The Present Worth Factor, Single Payment for Continuous Compounding for ten months and 100% is 0.4346; therefore the answer is \$1000 x 0.4346, or \$434.60.

6. What is the Present Worth of a continuous stream of payments, at a rate of \$100 per year, and continuing for 3½ years, if interest rate is 50%?

The Present Worth Factor -- constant steady stream for 3 years, 6 months and 50% interest is 1.652; therefore the answer is \$100 x 1.652, or \$165.20.

7. What is the Present Worth of a stream of income, continuously increasing at a constant rate, totalling $1000 in the first year,[1] and continuing for 4 years and 3 months, if interest rate is 100%?

   The Gradient Factor for continuous compounding for 100% and 4 years, 3 months is 1.850; therefore the answer is $1000 x 1.850, or $1850.00.

APPENDIX II

DERIVATION OF FORMULAE ON WHICH CERTAIN TABLES ARE BASED

1. Derivation of Gradient Factors -- Annual Compounding

   a. Grant has shown[2] that

$$R = \frac{g}{c} - \frac{ng}{i}\left[\frac{i}{(1+i)^n-1}\right]$$

   where

   R = Equivalent uniform annual equivalent
   g = Annual amount of increase, starting in the first year
   i = Annual interest rate
   n = Total number of years in series

   For ease of calculation, this was rewritten

$$R = g\left[\frac{1}{c} - \frac{n}{(1+i)^n-1}\right] \qquad (1)$$

   and values of the bracketed expression tabulated.

   b. To get Gradient Factor, Present Worth, it is only necessary to multiply equation (1) by the Present Worth Factor, Uniform series, or

[1] Note that this corresponds to an annual rate of increase of 2 x $1000, or $2000.

[2] Eugene L. Grant: Principles of Engineering Economy, 3rd Ed. The Ronald Press Company, New York, 1950. P. 551.

$$\frac{(1+i)^n-1}{i(1+i)^n}$$

giving, after some simplification

$$P = g\left[\frac{(1+i)^n-1-ni}{i^2(1+i)^n}\right] \qquad (2)$$

2. Derivation of Continuous Compounding Factor

a. It is well known[1] that the Present Worth, P, of a Single Payment, S, when nominal interest is j per cent per year, compounded instantaneously, and S occurs N years after the time of P, is given by

$$P = S\left[e^{-jN}\right] \qquad (3)$$

Bracketed values are tabled as Present Worth Factor, Single Payment, for Continuous Compounding.

b. The expression for the relationship between the Present Worth and Continuous Payments of a steady stream, can be obtained by substituting

$$\frac{Y}{c} \text{ for } R, \quad \frac{j}{c} \text{ for } i, \text{ and } Nc \text{ for } n$$

where Y = Total payments in one year (or yearly rate of payments)
c = Compounding per year
j = Nominal rate of interest, per year
N = Number of years

in the standard expression for Present Worth Factor, series payment, and evaluating the limit of this expression as c approaches infinity; or it may be obtained by setting up the general expression for the present worth of each individual payment and integrating over the time. This latter approach is presented here.

[1] For derivation see, for example, H. G. Thuesen: Engineering Economy, 2nd Edition, page 50. Prentice-Hall, Inc., 1957.

$$P = \int_0^{Nc} \frac{y}{c} e^{-\frac{j}{c}t} dt$$

$$= \frac{y}{c} \left[\frac{e^{-\frac{j}{c}t}}{\frac{-j}{c}} \right]_0^{Nc}$$

After substitution and simplification, this becomes

$$P = y\left[\frac{e^{jN}-1}{je^{jN}}\right] \qquad (4)$$

Values of the bracketed expression are tabulated.

c. Derivation of Gradient Factor - Continuous Compounding

Let G = Total payments in first year

g = The amount of increase of each payment over that made in previous instant

Then G = Average Payment x number of payments

$$G = \frac{0 + (c-1)g}{2} \times c$$

$$= \frac{(c-1)cg}{2}$$

As $c \rightarrow \infty$, this approaches

$$G = \frac{c^2 g}{2}$$

or $$g = \frac{2G}{c^2}$$

letting $$i = \frac{j}{c}$$

n = Nc as before, and substituting in Equation (2) yields

$$P = \frac{2G}{c^2}\left[\frac{(1+\frac{j}{c})^{Nc} - 1 - Nc\frac{j}{c}}{\frac{j^2}{c^2}\,(1+\frac{j}{c})^{Nc}}\right]$$

and recalling that

$$(1+\tfrac{j}{c})^{Nc} \longrightarrow e^{jN} \qquad \text{as } c \longrightarrow \infty$$

$$P = G\,\frac{2(e^{jN} - 1 - jN)}{j^2\, e^{jN}}$$

Values of the bracketed expression are tabulated for various values of N. and j.

* * *
*

Present Worth Factor - Single Payment - Annual Compounding

n	5%	10%	15%	20%	25%	30%
1	0.9524	0.9091	0.8695	0.8333	0.8000	0.7692
2	0.9070	0.8264	0.7561	0.6944	6400	0.5917
3	0.8638	0.7513	0.6575	0.5787	5120	0.4552
4	0.8227	0.6830	0.5718	0.4823	4096	0.3501
5	0.7835	0.6209	0.4972	0.4019	3277	0.2693
6	0.7462	0.5645	0.4323	0.3349	2621	0.2072
7	0.7107	0.5132	0.3759	0.2791	2097	0.1593
8	0.6768	0.4665	0.3269	0.2326	1678	0.1226
9	0.6446	0.4241	0.2842	0.1938	1342	0.0943
10	0.6139	0.3855	0.2472	0.1615	1074	0.0725
11	0.5847	0.3505	0.2149	0.1346	0.0859	0.0558
12	0.5568	0.3186	0.1869	0.1121	0.0687	0.0429
13	0.5303	0.2897	0.1625	0.0935	0.0550	0.0330
14	0.5051	0.2633	0.1413	0.0779	0.0440	0.0254
15	0.4810	0.2394	0.1229	0.0649	0.0352	0.0195
16	0.4581	0.2176	0.1069	0.0541	0.0281	0.0150
17	0.4363	0.1978	0.0929	0.0451	0.0225	0.0116
18	0.4155	0.1799	0.0808	0.0376	0.0180	0.0089
19	0.3957	0.1635	0.0703	0.0313	0.0144	0.0068
20	0.3769	0.1486	0.0611	0.0261	0.0115	0.0053
25	0.2953	0.0923	0.0304	0.0104	0.0038	0.0014
30	0.2313	.0573	0.0151	0.0042	0.0012	0.0004
35	0.1813	0.0356	0.0075	0.0017	0.0004	0.0001
40	0.1420	0.0221	0.0037	0.0007	0.0001	0.0000
45	0.1113	0.0137	0.0019	0.0003	0.0000	
50	0.0872	0.0085	0.0009	0.0001		

Present Worth Factor - Single Payment - Annual Compounding

n	35%	40%	45%	50%	55%	60%
1	0.7407	0.7143	0.6897	0.6667	0.6451	0.6250
2	0.5487	0.5102	0.4756	0.4444	0.4162	0.3906
3	0.4064	0.3644	0.3280	0.2963	0.2685	0.2441
4	0.3010	0.2603	0.2262	0.1975	0.1732	0.1526
5	0.2230	0.1859	0.1560	0.1317	0.1118	0.0954
6	0.1652	0.1328	0.1076	0.0878	0.0721	0.0596
7	0.1224	0.0949	0.0742	0.0585	0.0465	0.0372
8	0.0964	0.0678	0.0512	0.0390	0.0300	0.0233
9	0.0671	0.0484	0.0353	0.0260	0.0194	0.0146
10	0.0497	0.0346	0.0243	0.0173	0.0125	0.0091
11	0.0368	0.0247	0.0168	0.0116	0.0081	0.0057
12	0.0273	0.0176	0.0116	0.0077	0.0052	0.0036
13	0.0202	0.0126	0.0080	0.0051	0.0034	0.0022
14	0.0150	0.0090	0.0055	0.0034	0.0022	0.0014
15	0.0111	0.0064	0.0038	0.0023	0.0014	0.0009
16	0.0082	0.0046	0.0026	0.0015	0.0009	0.0005
17	0.0061	0.0033	0.0018	0.0010	0.0006	0.0003
18	0.0045	0.0023	0.0012	0.0007	0.0004	0.0002
19	0.0033	0.0017	0.0009	0.0005	0.0002	0.0001
20	0.0025	0.0012	0.0006	0.0003	0.0002	0.0001
25	0.0005	0.0002	0.0001	0.0000	0.0000	0.0000
30	0.0001	0.0000	0.0000			
35	0.0000					
40						
45						
50						

Present Worth Factor - Single Payment - Annual Compounding

n	65%	70%	75%	80%	85%	90%	95%	100%
1	0.6060	0.5882	0.5714	0.5556	0.5405	0.5263	0.5128	0.5000
2	0.3673	0.3400	0.3265	0.3086	0.2922	0.2770	0.2630	0.2500
3	0.2226	0.2035	0.1866	0.1715	0.1579	0.1458	0.1349	0.1250
4	0.1349	0.1197	0.1066	0.0953	0.0854	0.0767	0.0692	0.0625
5	0.0818	0.0704	0.0609	0.0529	0.0461	0.0404	0.0355	0.0312
6	0.0496	0.0414	0.0348	0.0294	0.0249	0.0213	0.0182	0.0156
7	0.0300	0.0243	0.0199	0.0163	0.0135	0.0112	0.0093	0.0028
8	0.0182	0.0143	0.0113	0.0091	0.0073	0.0059	0.0048	0.0039
9	0.0110	0.0084	0.0065	0.0050	0.0039	0.0031	0.0025	0.0020
10	0.0067	0.0050	0.0037	0.0028	0.0021	0.0016	0.0013	0.0010
11	0.0041	0.0029	0.0021	0.0016	0.0012	0.0009	0.0006	0.0005
12	0.0025	0.0017	0.0012	0.0009	0.0006	0.0005	0.0003	0.0002
13	0.0015	0.0010	0.0007	0.0005	0.0003	0.0002	0.0002	0.0001
14	0.0009	0.0006	0.0004	0.0003	0.0002	0.0001	0.0001	0.0001
15	0.0005	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000	0.0000
16	0.0003	0.0002	0.0001	0.0001	0.0001	0.0000		
17	0.0002	0.0001	0.0001					
18	0.0001	0.0001	0.0000					
19	0.0001	0.0000						
20	0.0000							